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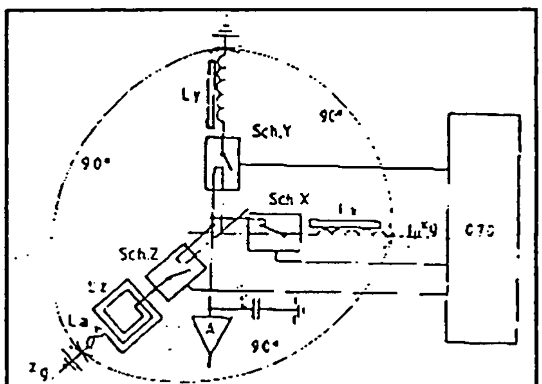

Fig. 9

An apparatus having a plurality of receiving coils for the avoidance of reception loss during a signal transmission with a magnetic field.

This apparatus employs for the reception of the magnetic field carrying a signal, a plurality of, but at least two, receiving coils having a predetermined angle between their geometric axes, said coils being so arranged in one or two opposed, vertical planes that the directions of their geometrical axes and also the direction of the axis of the sending coil may be either in one plane or optionally in space. These receiving coils are simultaneously inductors of the reception resonance circuit, and from each such resonance cycle, signal voltage is picked up at least one time during a self repeating reception cycle.

The apparatus presented in Fig. 9 (right, above) possesses three opposed, vertical receiving coil axes, "Lx", "Ly" and "Lz". The direction in space of these axes and also the axis of the sending coil may be optional.

For the enhancement of a resonance circuit, a conventional condenser "C" is employed. To this and simultaneously to the signal amplifier "A", the receiving coils are connected sequentially during each receiving cycle with electronic switches "Sch.x", "Sch.y" and "Sch. Z" which said switches are activated by a control (070). This apparatus is for an inductive transmission and signal transmission in a local area.

Translator
Morgan C. Larkin

CLAIMS

1. An apparatus for the avoidance of loss in signal because of the directional characteristics of sending and receiving coils, where a signal transmission with a magnetic field is concerned, therein characterized, in that there is employed for the reception of a magnetic field which carries a signal transmission, a plurality of, or at least two, receiving coils which have a characteristic angle between their geometric axes. Further, each receiving coil is also an inductor, either entirely or only partly so, of a resonance circuit correspondingly relating to the receiving frequency so that even in a free spatial disposition or in a planar optionally selected direction of the geometrical axes of the receiving coils or the sending coil, a signal voltage is induced and this signal voltage is picked up by a signal amplifier, said signal voltage being independent of any resonance circuit and isolated from all other resonance circuits.

2. An apparatus in accord with Claim 1, therein characterized in that for the receiving of the magnetic field carrying the signal, two receiving coils with opposed, vertical, geometric axes are employed.

3. An apparatus in accord with Claim 1, therein characterized in that for the receiving of the magnetic field carrying the signal, three receiving coils with opposed, vertical, geometric axes are used.

4. An apparatus in accord with Claim 1, therein characterized in that for the receiving of the magnetic field carrying the signal, three receiving coils, the geometric axes of which, or the projection of the same lie in a plane, are used and the angle between the geometric axes of two neighboring receiving coils is 60°.

5. An apparatus in accord with Claim 1, therein characterized in that the geometric axes of the coils employed for the reception of the magnetic field which carries the signal are disposed in two opposed, vertical planes.

6. An apparatus in accord with Claims 1 to 5, therein characterized in that for the reception of the magnetic field which carries the signal in any plane, three receiving coils are used, wherein a receiving coil, the geometric axis of which lies in a line of intersection of two planes is common to both planes and the angle between the geometric axes of two neighboring reception coils in one plane measures 60°.

7. An apparatus in accord with Claim 1, therein characterized in that the receiving coils used for the reception of the magnetic field which carries the signal possesses a ferrite core.

8. An apparatus in accord with Claim 1, therein characterized in that the coils used for the reception of the magnetic field which carries the signal are frame antennae.

9. An apparatus in accord with Claim 1, therein characterized in that for the reception of the magnetic field which carries the signal, three receiving coils with opposed vertical geometric axes are employed, wherein two receiving coils are ferrite antennae and the third coil is a frame antenna.

10. An apparatus in accord with Claims 1 to 9, therein characterized in that the intersection of the geometric axis of the frame antenna with the plane in which the geometric axes of the two ferrite antennae lie, is to be found in the angle between the said geometric axes of the two ferrite antennae.

11. An apparatus in accord with Claim 1, therein characterized in that the induced signal voltage from each resonance circuit is picked up by an isolated amplifier.

12. An apparatus in accord with Claim 1, therein characterized in that the received signal voltage from the parallely connected outputs of all amplifiers, which said outputs are also decoupled with disconnect members, is picked up.

13. An apparatus in accord with Claims 1 to 12, therein characterized in that demodulated signal voltage from the parallely connected signal rectifiers of all amplifiers, which signal rectifiers are decoupled with disconnect members, is picked up.

14. An apparatus in accord with Claim 1, therein characterized in that each of the resonance circuits formed with the receiving coils are connected by an electronic switch to a common signal amplifier for the acquisition of the induced signal voltage and this is executed one time and one time only, which time is correlated with a resonance circuit and during the interval of given length for the picking up of the induced signal voltage.

15. An apparatus in accord with Claims 1 to 14, therein characterized in that resonance circuit not directly connected to the signal amplifier is short circuited by means of electric switches, or is at least brought out of tuned alignment.

16. An apparatus in accord with Claims 1 to 15, therein characterized in that all those resonance circuits which include receiving coils are provided with a common mutual tuning condenser, to which, during a receiving cycle, each receiving coil is connected at least once by an electronic switch to serve as an inductor for such a resonance circuit.

17. An apparatus in accord with Claims 1 to 16, therein characterized in that the common tuning condenser is connected either directly, or with a coupling means, to the input of a common amplifier.

18. An apparatus in accord with Claims 1 to 17, therein characterized in that field effect transistors are employed as electronic switches.

19. An apparatus in accord with Claim 1, therein characterized in that for the transmission of a data content having a definite interval, this data content in its full interval is modulated to a high frequency impulse of an appropriate interval several times, but at least with a doubled product of the number of receiving coils which are used.

20. An apparatus in accord with Claim 1, therein characterized in that for the transmitting of a data content of definite interval, this data content is repeatedly transmitted with a number of high frequency impulses and each of these high frequency impulses transports this data content in its full completeness and encompassment and the number of these high frequency impulses is equal to at least the double product of the number of employed receiving coils.

DESCRIPTION

For the avoidance of a loss in reception caused by the directional characteristics of send and receive coils, where signal transmission with a magnetic field is concerned, corrective measures are in common knowledge which encompass a rotatable sending coil, a cross frame, or the utilization of a plurality of sending coils.

Disadvantages of the rotatable sending or receiving coils include complicated mechanical construction, the necessity of maintenance, and the necessary time for the adjustment of the axis of the coil. A quick and short-time signal transmission is ordinarily not possible with the said rotatable coil. For signal transmission over long distances, the directions of the geometrical axes in the case of both coils must be known, because even the directional pattern of the sending coil with one zero and a zone of zero emission is similar to a dipole.

Employing a plurality of sending coils, with permissible, optional directions of their axes in space, but with opposedly different and preset dispositions of their geometrical axes therein, so that the magnetic field carrying the signal from at least one sending coil must induce a signal voltage in the receiving coil at an optional direction of its electrical axis, does indeed avoid the above disadvantages, but the data must be emitted at least once with each sending coil and the consumed time proves greater than is necessary for a simple emission of the data and further, space must be allowed for the room necessary for the several sending coils.

The apparatus, which is here described, and which is suitable for an inductive signal transmission or for a signal transmission in a local zone does not have these deficiencies.

A sending coil is used for the activation of the magnetic field which carries the signal and correspondingly, the combination of the employed reception coils may have the direction of their axes optionally in space or at least in one plane. For the receiving of its field there are used several, or at least two, receiving coils at a given fixed angle a, defined by the number of coils and operational objective of the apparatus, said angle being

between their geometric axes but in an optional direction of said axes in space or at least in one plane.

The voltage "U" induced in a receiving coil is a function of the angle φ between the vertical line through the midpoint of the receiving coil to its plane of the electrical axis, and the direction of the magnetic field. In this respect, $U = A \cdot \cos \varphi$ and is at maximum when $\varphi = 0°$.

The vertical through the midpoint of the receiving coil to the plane of its electrical axis, is identical to the geometric axis of the receiving coil. The constant "A" is dependent upon the intensity of the magnetic field through the receiving coil and upon its construction.

The number of the receiving coils and the angle a between its geometric axes are so selected that in an optional direction of the axis, the sending coil, either in a plane, or in the space of the electric axis with at least one receiving coil opposed to the magnetic field which carries the signal has such a direction that a signal voltage must be induced therein.

In Fig. 1 is an example with two receiving coils *Lx*, *Ly*, the geometric axes "*xg*" and "*yg*" of which lie in a horizontal plane and the angle between their geometric axes reads $a = 90°$. This arrangement makes possible, as is presented in Figs. 3 and 4, a signal reception at an optional direction of the geometrical axis of the sending coil in the horizontal plane and an optional direction of the geometrical axes of the receiving coils in the horizontal plane. This is in the range of inductive transmission and possible for not too distant operation because the magnetic field which carries the signal of the sending coil "*Ls*" is equal to, or at least approaches the field of a solenoid. The angle $\varphi x = 0°$ and is minimal between the tangent to a field line "*tx*" and the geometric axis "*xg*" of the receiving coil "*Lx*" and the signal voltage is only induced in the coil "*Lx*" in the case that the coil "*Ly*" is the angle $\varphi x = 90°$ and the induced signal voltage $U = 0$. In the case of a geometric axis "*sg*" which is turned 90°, the sending coil "*Ls*", as presented in Fig. 4, exhibits the angle $\varphi x = 0°$ between the tangent "*ty*" and that of the geometric axis "*yg*" of the receiving coil "*Ly*", which signal voltage is only induced in the receiving coil "*Ly*" and $U = 0$ in the coil "*Lx*". Each receiving coil is the inductor of a resonant circuit tuned

to the sending frequency from which, subsequently, the signal is obtained. Both resonant circuits are galvanically coupled, each resonance circuit is connected to its own amplifier "*A*". The magnetic coupling between the resonance circuits must also be small, the resonance circuit dare not be influenced. If the phase difference of both induced signal voltages are small, then, with resistance "*R*" decoupled and by means of the parallely connected outputs of both amplifiers "*A*", the signal voltage is removed.

In Fig. 2 is an arrangement of three receiving coils, "*Lx*", *Ly*", "*Lz*", with opposed vertical geometrical axes, in which case the directions of the geometrical axes of the sending coils in space may be optional. Each receiving coil is an induction of a resonance circuit tuned to the sender frequency and each resonance circuit is connected to an amplifier "*A*". This is simultaneously an example of a case where the resonance circuit induced signal possesses different phases and the outputs coupled with the resistances "*R*" of the signal rectifier "*G*" can be connected in parallel and then the demodulated signal voltage can be removed.

In Fig. 5 is presented an arrangement of five receiving coils, the geometric axes of which lie in two opposed, vertical planes, i.e., in the horizontal plane "*X*" and the vertical plane "*Y*". The geometric axis of the sending coil "*Ls*", may then have an optional direction in space and an advantage of this arrangement of the receiving coils is marked by smaller swings of the evoked signal voltage which arises at the output of the apparatus as a function of the direction of the geometrical exits of the sending coil "*Ls*". In each plane three receiving coils are used for signal acquisition, in the plane "*X*", these are "Lx_1", "Lx_2", "*Lxy*", in the plane "*Y*" we have "Ly_1", "Ly_2", "*Lxy*". The receiving coil "*Lxy*" is common for both planes. The angle "*a*" between two, single plane geometric axes of two neighboring receiving coils measures $a = 60°$. Only the directions of the geometric axes of the receiving coils as opposed to the direction of the emission of the magnetic field which carries the signal are of importance and these remain intact even if, for example, the "*Lx*" receiving coils are found in a line as presented in Fig. 6 or yet if the "*Ly*" receiving coils, that is, all receiving coils, are found in the horizontal plane (see Figs. 6, 7).

In apparatuses, where the receiving coils, because of space restrictions, must find themselves at small distances from one another and their mutual inductive coupling cannot be eliminated, but the resonance circuit cannot be influenced, in this case it is possible to circumvent this difficulty, in that in a moment and during a time interval of interval "t_e" the signal circuits taken from a resonance circuit and only this is connected to an electronic switch to the signal amplifier. The remainder resonance circuits can then be short circuited with electronic switches, or at least brought out of tune.

In Fig. 8 is an example of an apparatus with two receiving coils, *"Lx"* and *"Ly"* with mutually vertical geometric axes *"xg"* and *"yg"*, which lie in horizontal planes, the direction, then, of the geometrical axis *"sg"* of the sending coil *"Ls"* may then be in an optional horizontal plane. The electronic switch *"Sch.X"* for the connection of the resonance circuit along with the receiving coil *"Lx"* during a receiving time *"te"* to the signal amplifier *"A"* or for the short circuiting of this resonance circuit and the electronic switch *"Sch.Y"* with a similar function to the resonance circuit with the receiving coil are activated by the control switch box (070). The signal voltage is removed from the resolution circuit in a periodically repeating receiving cycle and each resonance circuit during this receiving circuit, along with its electronic switch in a time point allotted only thereto, and during a receiving time *"te"* is connected to a signal amplifier "A". This receiving cycle repeats itself periodically. Following the pick-up of the signal voltage from the last resonance circuit, the signal voltage is again picked-up from the first resonance circuit. The interval "t_{ez}" of a reception cycle is dependent upon the nature of the of the emitting of these data. In Fig. 11, there is shown the impulse diagram of the arrangement of Fig. 8, which data are in the form of non-modulated HF impulses emitted at a interval "t_s". The receiving coil *"Lx"* is in a situation in which "φ_x" = 0° and the induced voltage "U_x" therein is maximal, the receiving coil *"Ly"* must simultaneously be in the condition in which "φ_y" = 90° and the therein induced voltage *"U"* is equal to null, i.e. $U = 0$.

The interval "t_{ez}" of a receiving cycle is given with the number *"a"* of the receiving coils, with which the reception time "t_e" necessary for the certified reception of the transmitted information by the HF impulse with an optional receiving coil and in the

case of an optional position of the HF impulse against the receiving cycle, and further with the time "t_{α}", which is the time without reception, and that is the time between two subsequently following reception time "t_e" of two reception coils. The minimal necessary interval of a reception cycle is then $t_{ez} = a \cdot t_e min + (a - 1)t_{\alpha}$. The minimal necessary receiving time with an optional coil is: $t_e min = 2 \cdot t_{ie} min + t_{\alpha}$ wherein $t_{ie} min$ is the minimal necessary time for the transmission of the data with assured reception using an optional coil. This time," $t_{ie} min$", conforms to the transmitted data, the connection time for the electronic switches, and the read-out time of the amplifier *"A"*. The reception time *"$t_e min$"* must then be represented by the interval: $t_e min = 2 \cdot t_{ie} min + t_{\alpha}$ because, as is presented in Fig. 11, line "induced voltage in coil and cycle" in the cycle *"n"* and in the cycle *"n - 1"*, the *"$t_{ie} min$"* must, even in the case of an unfavorable position of the HF impulses remain in secured condition in the reception cycle. From the impulse diagram in Fig. 11, one may also see, that each HF impulse sent in an optional point of time, with at least one reception cycle *"t_{ez}"* is received and each time in the resonance circuit with the receiving coil *"Lx"* a signal voltage is induced during a time interval of interval $t_{ind} = t_{ie} min$.

The interval of the HF impulse is: $t_s = t_{ez}$. When an emitted HF impulse, during two reception times *"t_e"* which belong to two reception cycles following one another of a resonance cycle are received, during these HF impulses interval *"t_s"* the signal voltage in this resonance circuit is doubly induced. In Fig. 11, this is the case where the HF impulse *"m"* is received during the n^{th} and the $(n + 1)^{th}$. With an HF impulse of a definite interval *"t_s"* only a data content of a definite interval *"t_i"* will be transmitted, for the transmission of a data content of a interval $k \cdot t_n$ then at least *k*-HF impulses and *k*-receiving cycles are necessary.

An apparatus with three receiving coils, *"Lx"*, *"Ly"*, *"Lz"* having opposed, vertical, geometrical axes *"xg"*, *"yg"*, *"zg"*, which permit a signal transmission in a case where an optional direction of the geometric axis *"sg"* of the sending coil *"Ls"* in space, is shown in Fig. 9. The inductors *[i.e. coils]* *"Lx"*, *"Ly"*, *"Lz"* of the three resonance circuits have a common tuning condenser *"C"*.

The reception coils are connected singly by means of electronic switches "*Sch. X*", "*Sch. Y*" and "*Sch.Z*" to this said condenser and simultaneously to the amplifier "*A*", each time only at a particular instant correlated with a receiving coil. The resonance circuit is thus completed and the signal voltage is picked up. Field effect transistors are employed as switches, since a circulation current flows through receiving coils of the resonance circuit. The receiving coil "*Lz*" is a frame antenna and its induction is balanced by the compensation coil "*La*" against the resonance frequency. In Fig. 10, the receiving coils portrayed as "*Lx*" and "*Ly*" are ferrite antennae and the "*Lz*" is a frame antenna, this combination is flat and permits a flat construction of equipment which is a particularly advantageous feature in portable and pocket units. In Fig. 12 are the impulse diagrams belonging to the arrangement of Fig. 9.

A presupposition for receiving with the procedure as shown in accord with impulse diagrams Fig. 11, 12, is non-changeable data content during the entire interval "t_s" of the emission of the HF impulses, so that with an optional receiving coil during the receiving time "$t_{iz} min$" in an optional section of the HF impulses, always the complete data content will be received.

If the data content alter itself, during an emission interval "t_i" and, during the said interval "t_i" is received in completeness without interruption, then this data content must be received during at least one receiving cycle with at least one receiving coil, likewise, in completeness without interruption during its entire interval "t_i". This is possible with the proposed apparatus when this data content is emitted w-times during the HF impulse. Impulse diagrams of such a period of emission with such a data content "t_i" are presented in Figs. 13, 14 and refer to the arrangement shown in Fig. 9. For simplification, an ideal case has been assumed in the impulse diagram Fig. 13, wherein the response and decay periods "t_a" of the electronic switch are negligible — conversely, in Fig. 14 these intervals are given consideration. In this case the number "*a*" of the receiving coils is determined by the required and permissible changes of the directions of the geometric axes of the receiving coils and the sending coil "L_s" as well as with the permissible fluctuations of the induced voltage in the receiving coils.

The same rules hold as those for the previous case of transmission having a non-modulated or a modulated HF impulse of an interval "t_s" which has non-variable data content. Fig. 14 makes evident that a changeable data content of an interval "t_i" repeats w-times on the HF impulse of an interval "t_s", whereby the number "w" of the repeats $w = 2a$ must be emitted. In the example shown in Fig. 14, essentially in the matter of the receiving coil "*Lx*" the geometric axis "*xg*" finds itself in such a direction in relation to the magnetic field which carries the signal, that a signal voltage is induced in the receiving coil "*Lx*". The HF impulse of an interval "t_s" in line 4, finds itself in an unfavorable position in relation to the receiving cycles *(n-1)*, *n*, and *(n + 1)* of line 5. The "t_i" transmitted data content with the HF impulse "t_s" (1) is received upon its emission during the switched connection which belongs to the n[th] reception cycle and on its (6) repetition during the switched connection of the "*Lx*" which corresponds to the *(n + 1)* receiving cycle in its full interval, see lines 5, 6. During the n[th] receiving cycle 5, 6, the reception coil "*Lx*" completely receives also the (6) repeat of the transmitted data content of the HF impulse, "t_s"*(0)*. During the *(n + 1)* receiving cycle, the "*Lx*" coil receives completely also the (1) emission of the data content transmitted by the HF impulse "$t_s(2)$". Upon a shift of the HF impulse, "$t_s(1)$" to the right, the data content transmitted thereby is not completely received upon its (1) emission, however, is completely received during its (6) repetition in the same HF impulse "t_s *(1)*" and during the *(n + 1)* reception cycle with the coil "*Lx*".

This leaves to be determined for an assured reception of an emitted data content:

- an interval "t_i",
- by a given number "*a*" of receiving coils with an optional position of the HF impulse to the minimum necessary intervals "t_s" for the said HF receiving cycles, and
- the minimum necessary interval "t_{ez}" of the receiving cycles.

The interval "t_s" of the HF impulse in the case of a w-times repeated emission of a data content interval "t_t" is comprised of the "$w \cdot t_t$" interval emission intervals of the data and of a $(w - 1) \cdot t_{oi}$ interval of interval without emission of the data and is: $t_s = w \cdot t_t + (w - 1) \cdot t_{oi}$. The interval "$t_i$" given, the interval "$t_{oi}$", without emission of data is the interval between two neighboring emissions of the data and also the interval between two neighboring HF impulses. The interval "t_{oi}" possesses a timing conditioned by the design of the sender, which cannot be diminished. However, above this threshold is it freely to be chosen optionally and is used for the conformation of the interval "t_s" of the HF impulse to its normal time span.

The interval "t_{ez}" of a receiving cycle is: $t_{ez} = a \cdot t_e + (a - 1) \cdot t_{oe}$ wherein the interval "t_e" is that by a given time "t_i" and "t_{oi}" minimal, necessary receiving interval with an optional receiving coil and by an optimal position of the HF impulse to the receiving cycle for a complete reception of the emitted data content of the interval "t_t". The time span "t_{oe}" is the interval passing without receiving and that is further the time between two neighboring receiving intervals "t_e" of two receiving coils. The minimal necessary receiving interval "t_e" with an optional receiving coil is, as is indicated in Fig. 14, line 1, "HF Impulse"; line 2, "Receiving cycles"; line 3, Induced volts in coil during cycle; all given for a simple and single reception of the emitted data content during an interval "t_i" needed for receiving time, and this is: $t_{ie} = t_h$, wherein the longest interval yet to be awaited, "t_i" is inserted along with the time span "t_{oi}" and with the response and decay periods "t_s" of the electronic switches which are employed.

The minimum required reception interval "t_e" for a receiving coil is $t_e = 2t_{ie} + t_{oi} + 2t_a$ and the necessary interval "t_{oi}" is $t_{oi} = 2t_s + t_{oe}$. Since "t_{oe}" is the longest interval "t_{oe}" in action, these influence the interval of intervals "t_s" of the HF impulses and are restrained to be as short as possible. The necessary interval of the HF impulse is shown by: $t_s = w + t_i + (w + t) \cdot t_{oi}$ and the interval "t_{ez}" of a receiving cycle is expressed by: $t_{ez} = a \cdot t_e + (a - 1) \cdot t_{oe}$. In the case of an emission of a shorter data content "t_t", provided as maximal, the interval "t_{oi}" must be extended, so that the interval "t_s" of the HF impulse remains unchanged or then also the interval "t_{ez}" of the receiving

cycle must be determined anew.

In the impulse diagrams as shown in Fig. 13, the assumption has been made, that the response and decay of the electronic switch are negligible, in which case then, $t_{oi} = t_{oe}$. Instead of an HF impulse of period "t_s" with a w-times data content which has been modulated, an interval "t_i" can also be used a "w" HF impulse for each of a time span interval "t_i" with generally the same modulated data content of interval "t_i"and the time span "t_{oi}" between two neighboring HF impulses remains at the same interval interval as the time "t_{oi}" between two neighboring modulations on the data content in the case of a transmission with an HF impulse interval "t_s".

The described apparatus makes possible a reliable signal reception in the case of a signal transmission of exclusively magnetic field type, and in the areas of an inductive transmission and a transmission in local range even when the direction of the axis of the sending coil is not known and must be optional and also when the direction of the axes of the receiving coils cannot freely be determined, so that even under such conditions, it is possible to fully exploit the advantages of this signal transmission.

[This completes the assigned text]

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Anmeldetag: 1. Februar 1986
Offenlegungstag: 8. Januar 1987

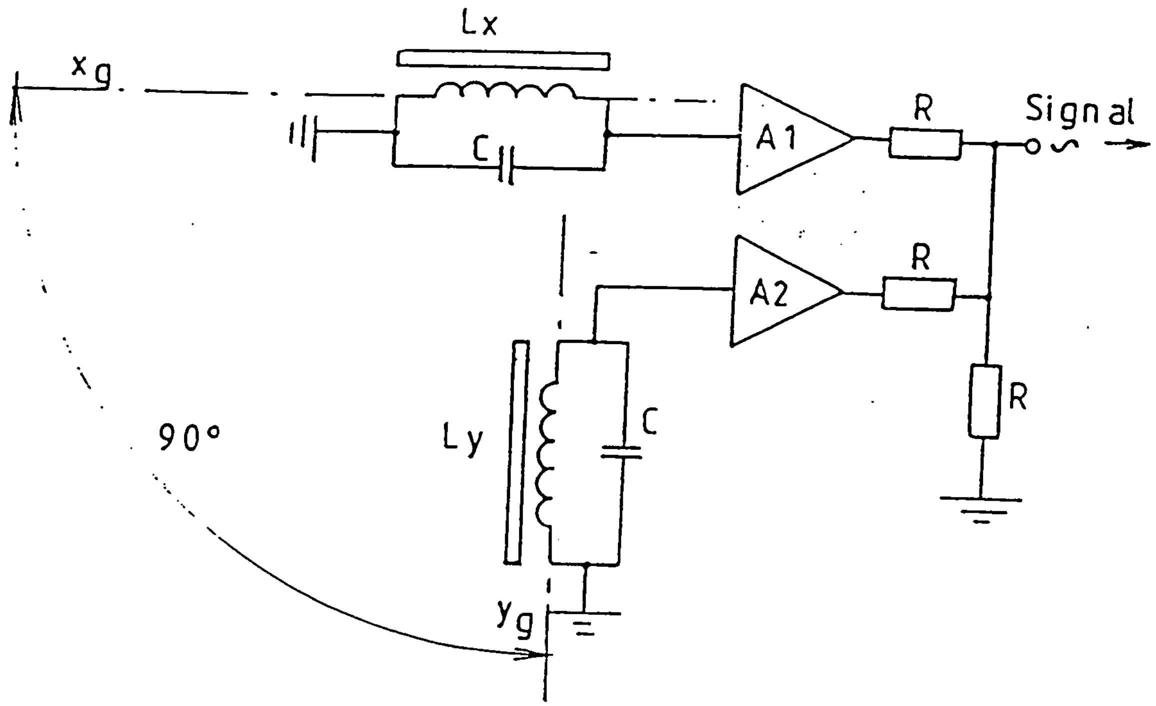


Fig. 1.

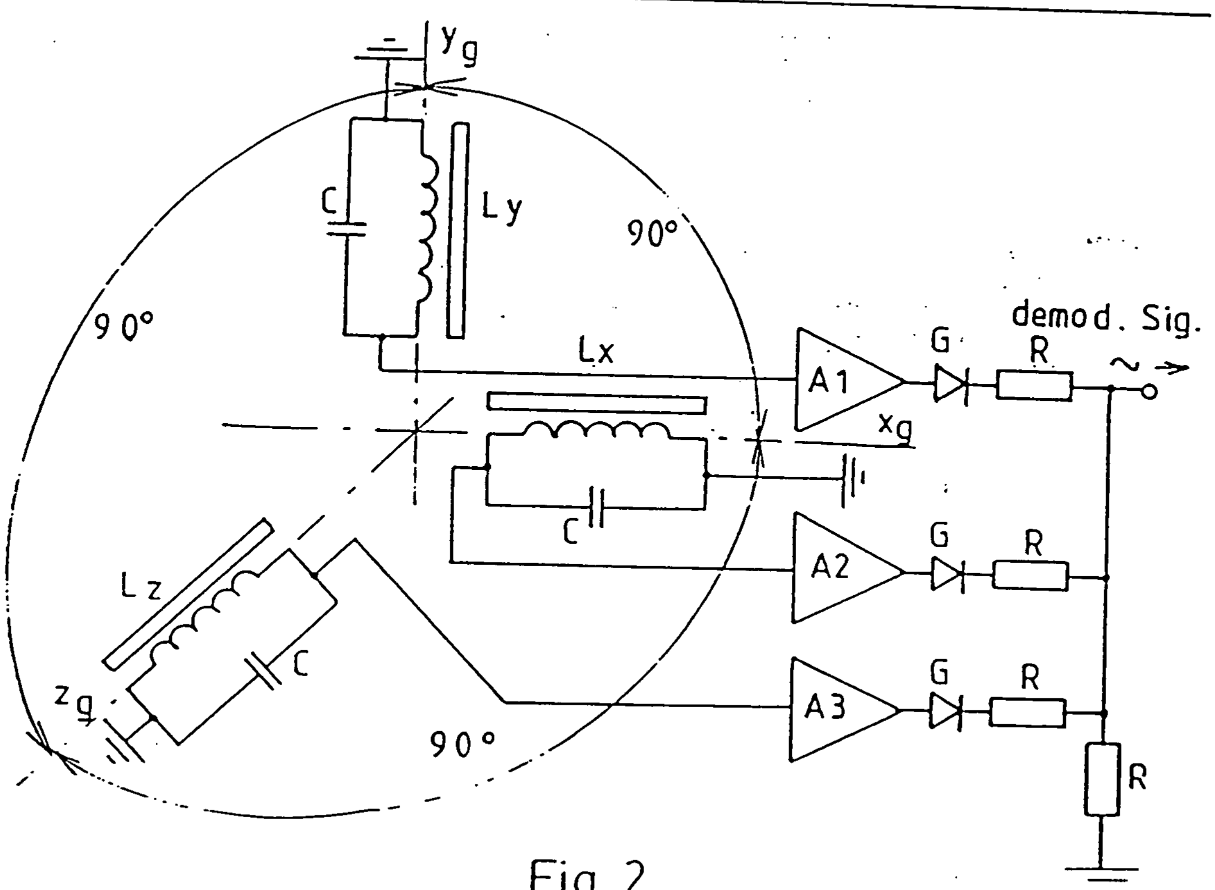
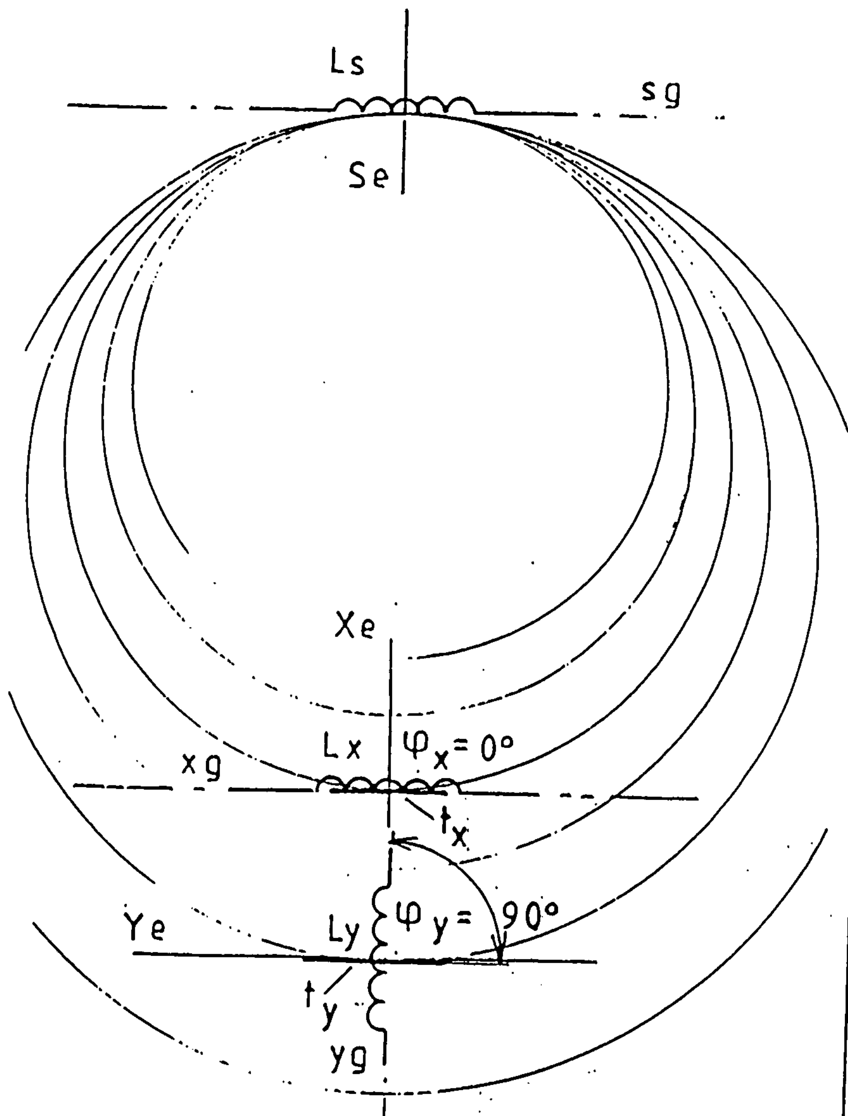


Fig. 2.


Ls
sg
Se
Xe
Lx
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xg
t_x
Ye
Ly
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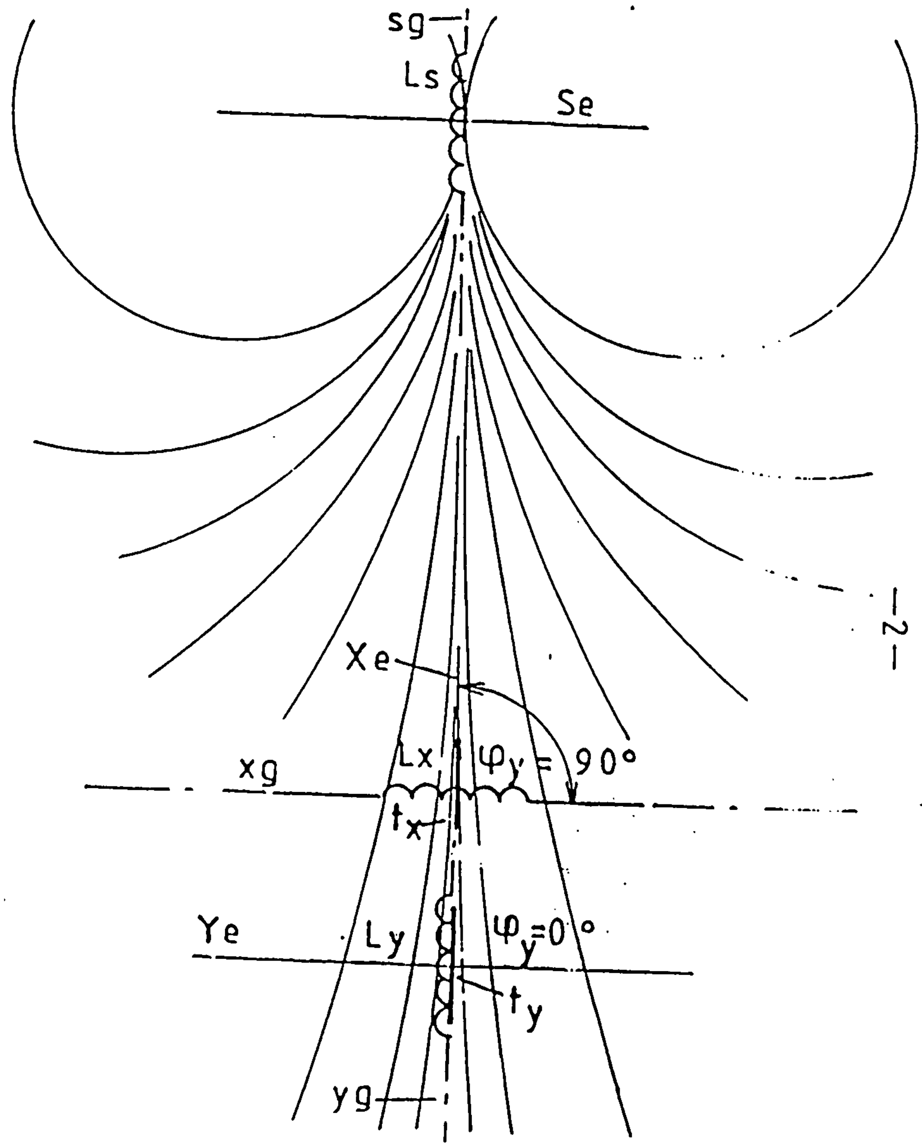
t_y
yg

Fig. 3.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Ls
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t_y
yg

Fig. 4.

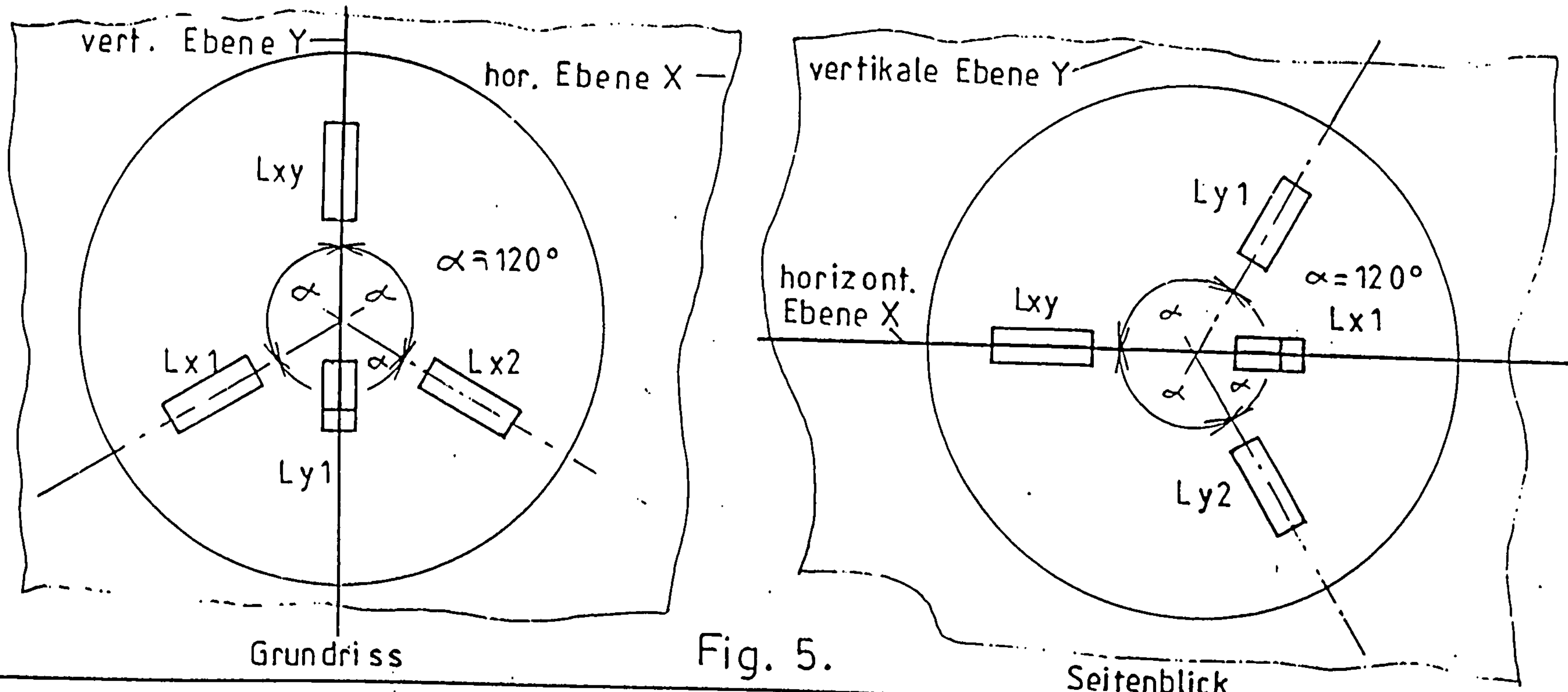


Fig. 5.

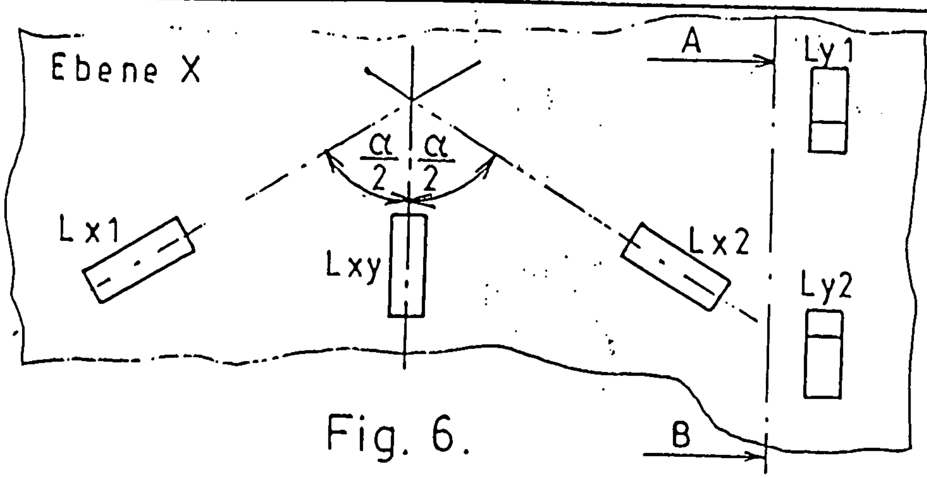


Fig. 6.

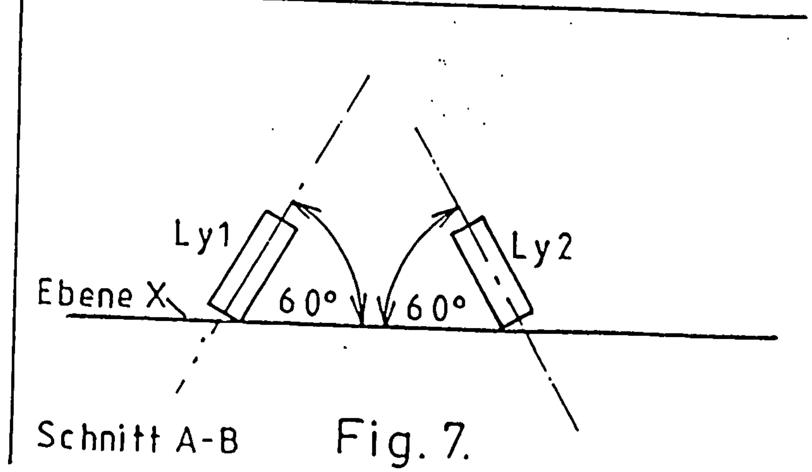
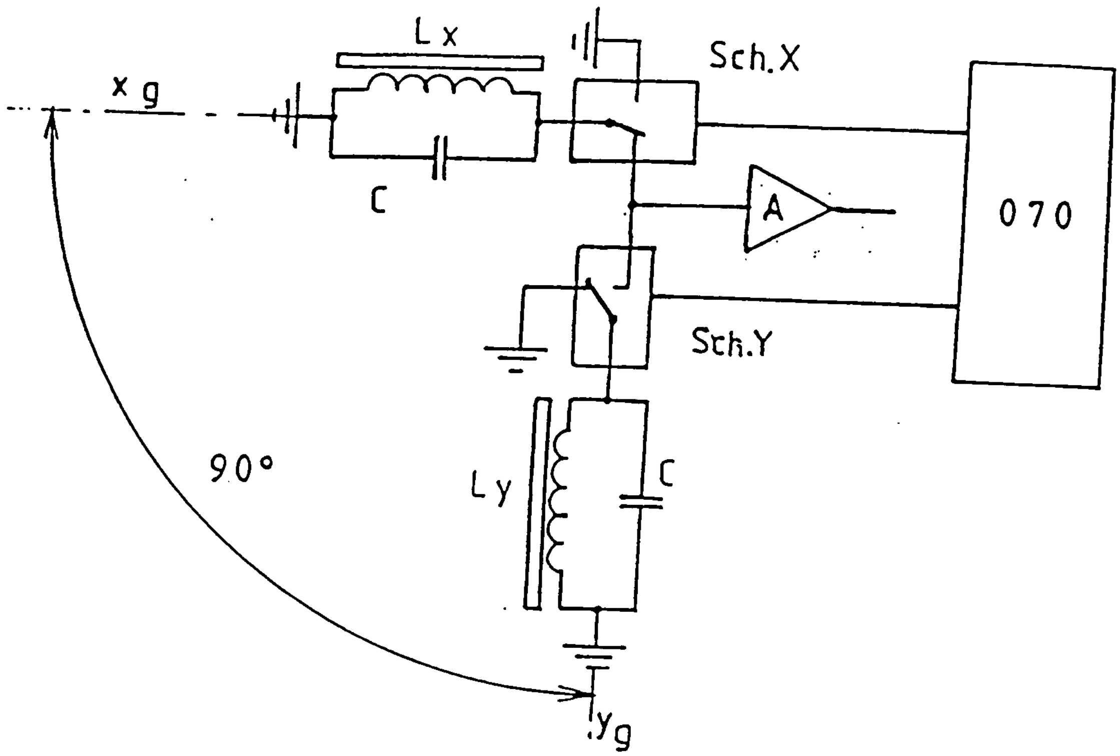
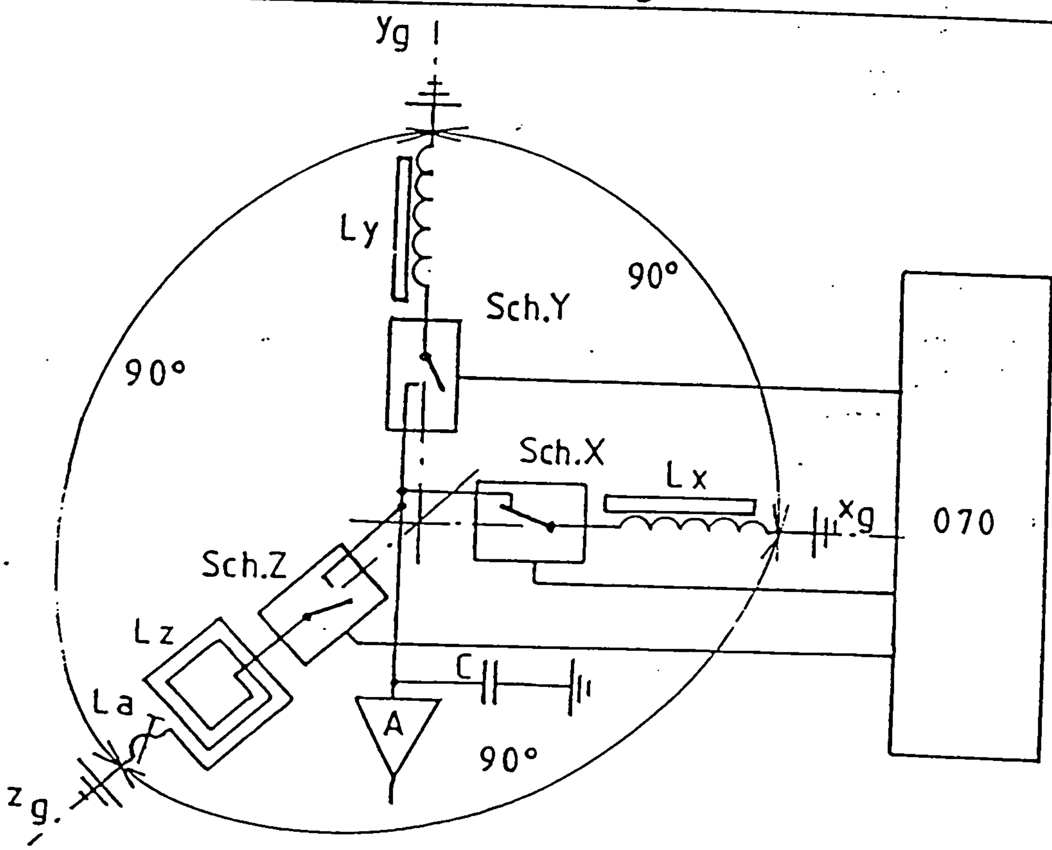


Fig. 7.



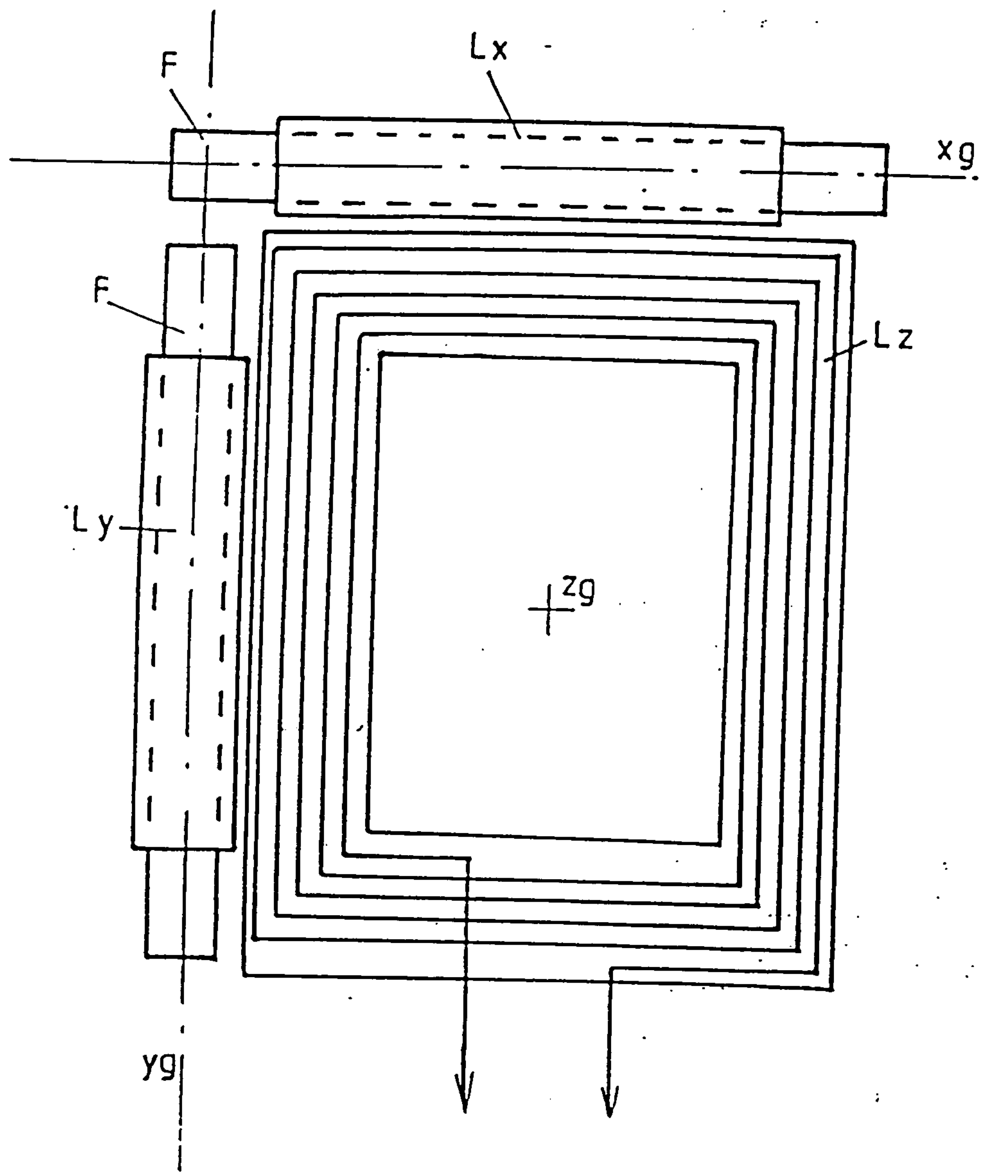
Lx
xg
Sch.X
A
070
C
Sch.Y
90°
Ly
C
yg

Fig. 8



yg
Ly
90°
Sch.Y
90°
Sch.X
Lx
xg
070
Sch.Z
Lz
La
C
A
90°
zg.

Fig. 9



Fi g. 10.

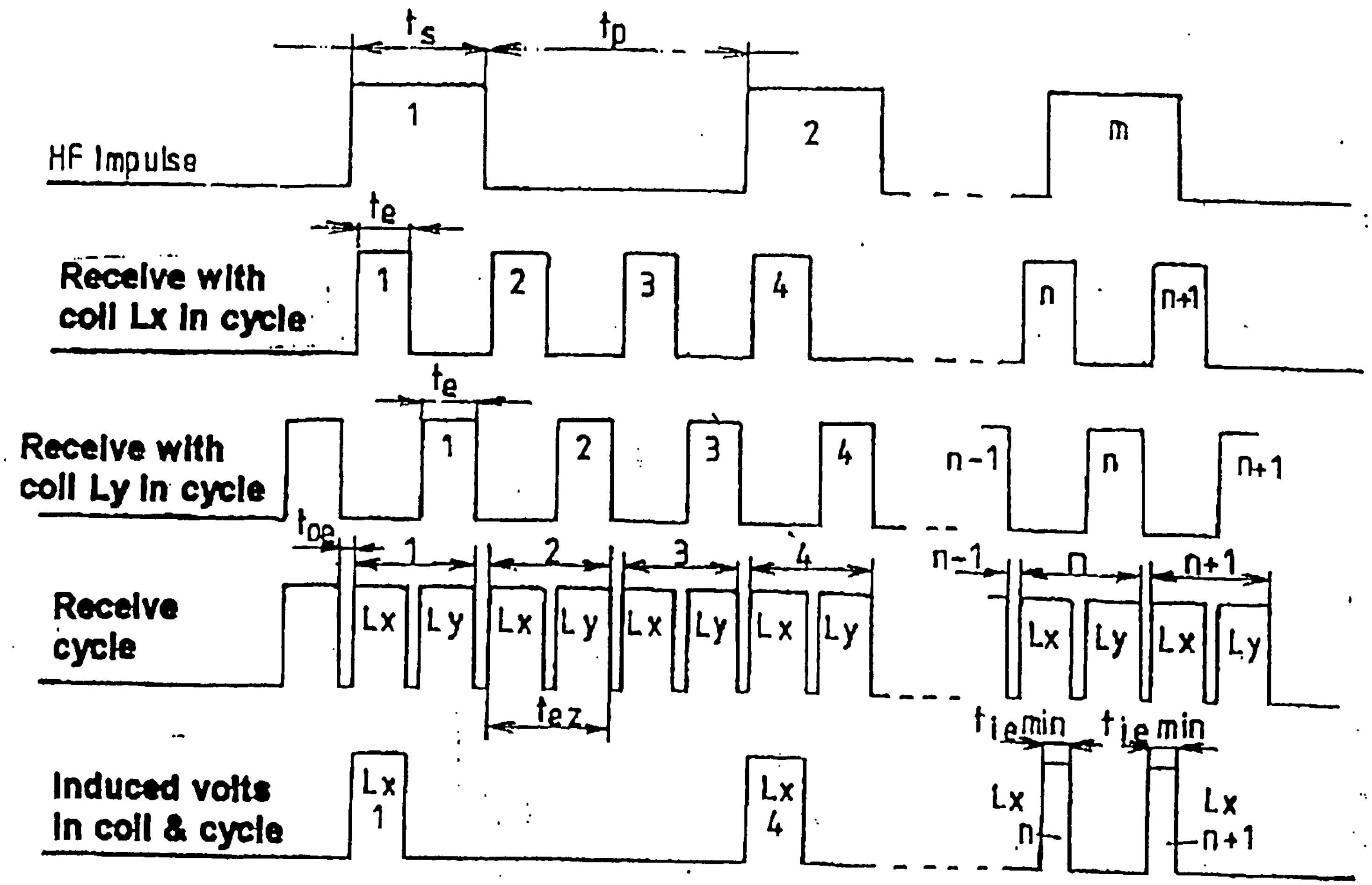
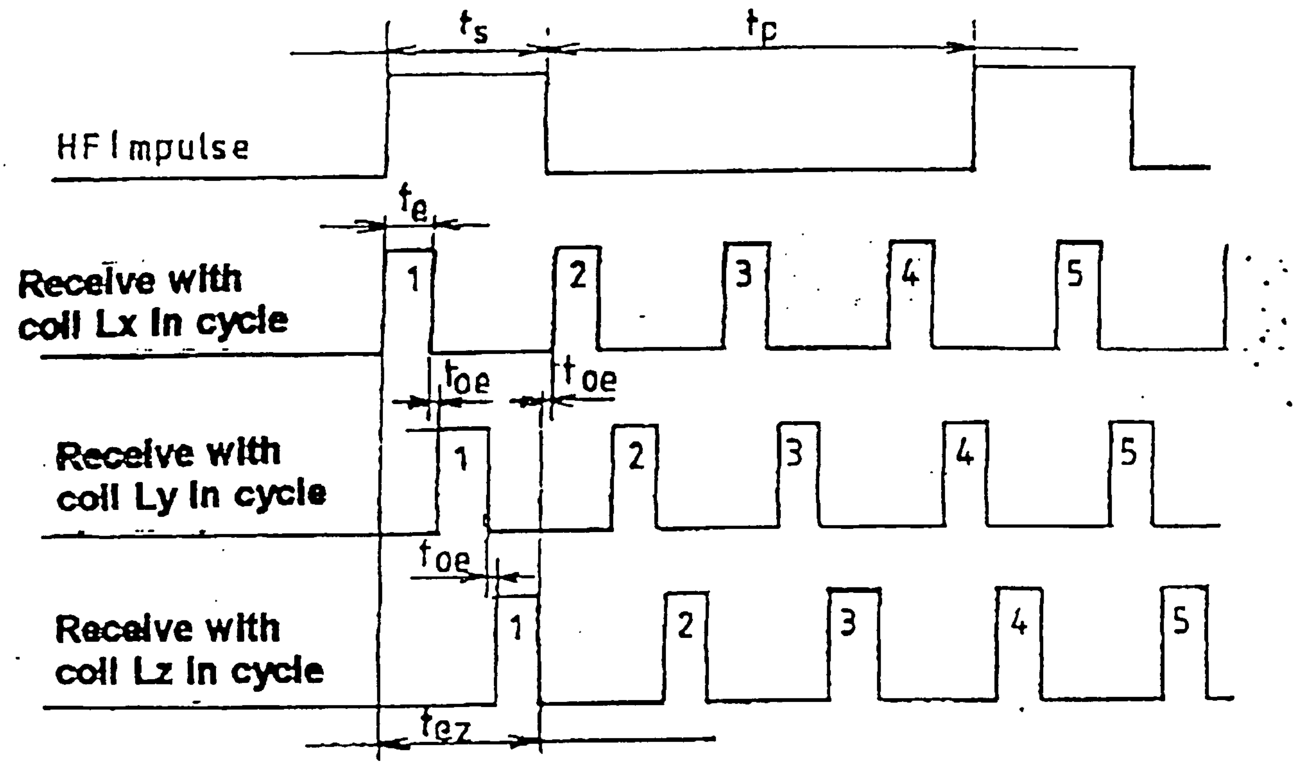
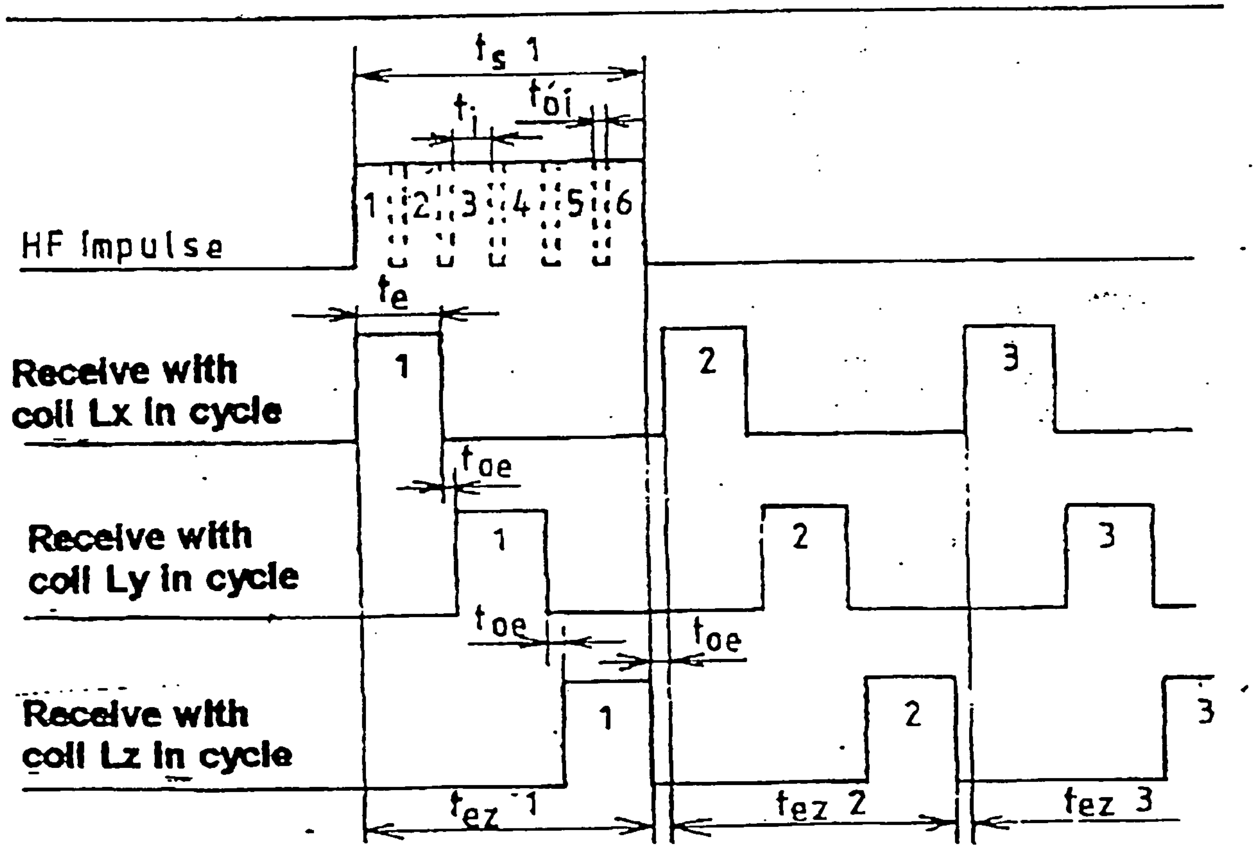

HF Impulse
Receive with coil Lx in cycle
Receive with coil Ly in cycle
Receive cycle
Induced volts in coil & cycle
t_s
t_p
t_e
t_{oe}
t_{ez}
$t_{ie\,min}$
1
2
m
3
4
n-1
n
n+1
Lx
Ly

Fig. 11.



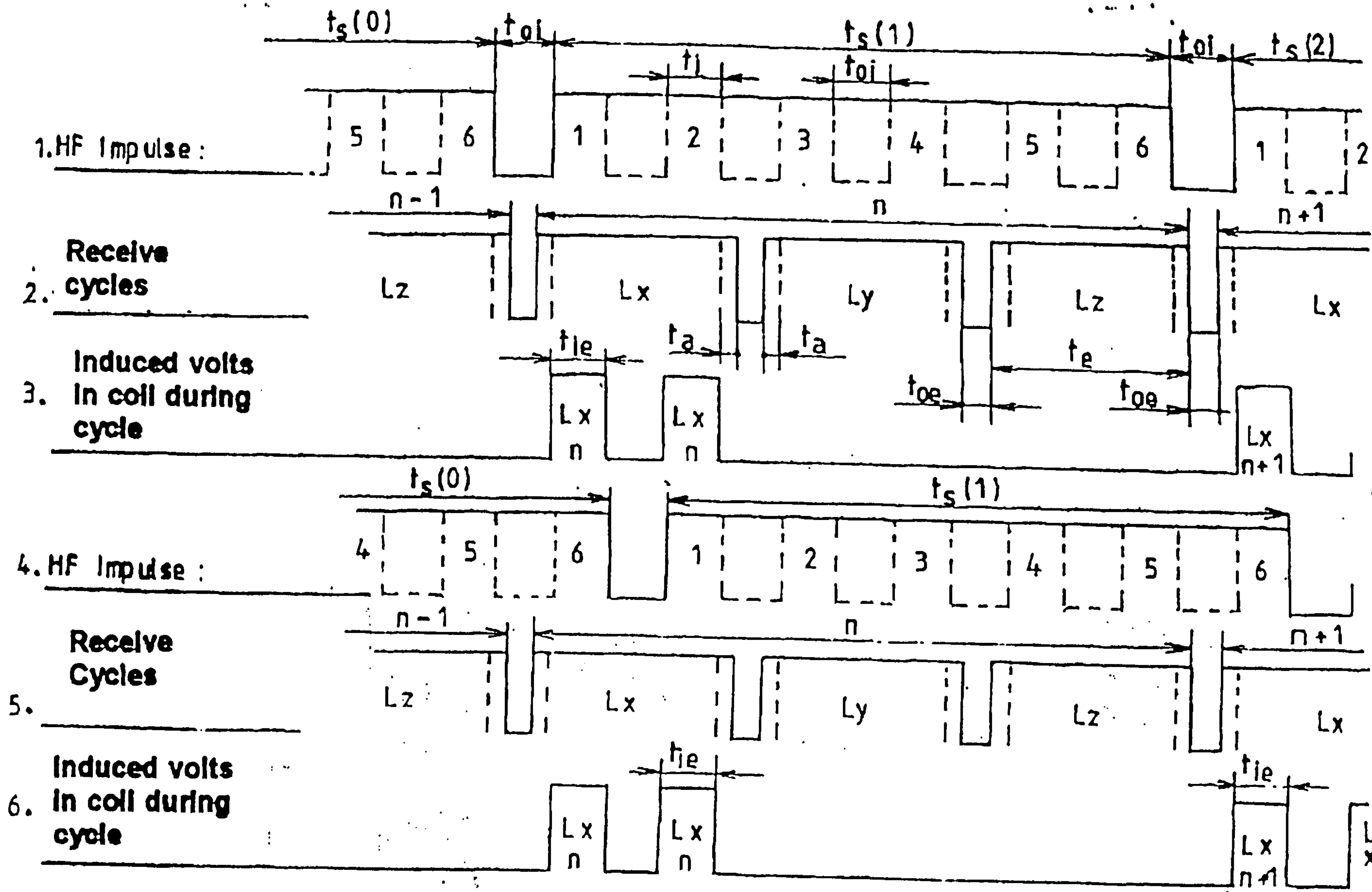
t_s
t_p
HF Impulse
t_e
Receive with coil Lx in cycle
1
2
3
4
5
t_{oe}
t_{oe}
Receive with coil Ly in cycle
1
2
3
4
5
t_{oe}
Receive with coil Lz in cycle
1
2
3
4
5
t_{ez}

Fig.12.



t_s 1
t_i
t_{oi}
1
2
3
4
5
6
HF Impulse
t_e
Receive with coil Lx in cycle
1
2
3
t_{oe}
Receive with coil Ly in cycle
1
2
3
t_{oe}
t_{oe}
Receive with coil Lz in cycle
1
2
3
t_{ez} 1
t_{ez} 2
t_{ez} 3

Fig.13.



1.HF Impulse :
2. Receive cycles
3. Induced volts in coil during cycle
4. HF Impulse :
5. Receive Cycles
6. Induced volts in coil during cycle
$t_s(0)$
t_{oi}
$t_s(1)$
t_i
$t_s(2)$
n - 1
n
n + 1
Lz
Lx
Ly
t_{le}
t_a
t_e
t_{oe}

Fig. 14.